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Development and Analyses of a New Ideal Finishing Appliance

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DEVELOPMENT AND ANALYSES OF A NEW IDEAL FINISHING APPLIANCE

by

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TABLE OF CONTENTS

	Page
INTRODUCTION	1
METHODS AND MATERIALS	4
RESULTS	10
DISCUSSION	27
SUMMARY	37
BIBLIOGRAPHY	38

LIST OF TABLES

Table		Page
I	Mean force required to displace each maxillary flexible component 1 mm.	15
II	Mean force required to displace each mandibular flexible component 1 mm.	16
III	Mean force and displacement of each mandibular flexible component required to replace each flexible component following activation of the right cuspid	17
IV	Mean force and displacement of each mandibular flexible component required to replace each flexible component following right first and second bicuspid activations	18
V	Mean force and displacement of each mandibular flexible component required to replace each flexible component following bilateral first and second bicuspid activations	19
VI	Mean force and displacement of each maxillary flexible component required to replace each flexible component following the four incisor intrusion or extrusion activations	20
VII	Mean force and displacement of each mandibular flexible component required to replace each flexible component following bilateral cuspid activations	21
VIII	Mean force and displacement of each maxillary flexible component required to replace each flexible component following the four incisor lingual root torque activations	22
IX	Mean force and displacement of each maxillary flexible component required to replace each flexible component following bilateral cuspid and four incisor lingual root torque activations	23
X	The reciprocal force and displacement of each mandibular flexible component by immobilization of molar flexible components following bilateral cuspid activations	24

Table		Page
XI	The reciprocal force and displacement of each maxillary flexible component by immobilization of molar flexible components following four incisor lingual root torque activations	25
XII	The reciprocal force and displacement of each maxillary flexible component by immobilization of molar flexible component following bilateral cuspid and the four incisor lingual root torque activations	26

LIST OF FIGURES

Figure		Page
1A	Frontal views of the ideal model with the BAP appliance	6
1B	Right and left lateral views of the BAP appliance	7
2	Illustrations of measuring devices	8

The following manuscript was prepared as a partial fulfillment of the requirements for a graduate degree from Loma Linda University Graduate School under the discipline of the School of Dentistry.

While the format in general is governed by the criteria of a conventional Graduate School Thesis, it is in actuality a manuscript which readily is amenable for publication in a scientific journal.

INTRODUCTION

Orthodontists have developed various techniques to move teeth during the finishing stages of treatment. Various types of attachments are now available which enable the force produced by the deformation of the continuous or segmental arch wire to be transmitted to the teeth. However, all of these conventional banded techniques possess several major deficiencies.

First, a fundamental premise upon which all appliance theory is based is Newton's Third Law of Motion, "For every action there is an equal and opposite reaction." These reactional forces generally result in undesirable movements of the adjacent teeth and make it difficult to tailor optimum forces to each tooth. For example, whenever lingual root torque forces are applied to the cuspid while in a continuous finishing arch wire, reciprocal labial or buccal root torque forces are exerted to the lateral incisor and the bicuspid teeth or if intrusion forces are applied to the four incisors, there is a considerable amount of reciprocal extrusion force exerted to the cuspid and progressively less to the bicuspids. Second, there is minimum activation force storage designed into the conventional finishing arch wire because of its rigidity which limits its flexibility. Third, arch wire adjustments are very time-consuming since they require the removal of the entire arch wire even for a single tooth reactivation. Fourth, the bracket location becomes very critical during the conventional final finishing stages of treatment because it determines the three dimensional position of each tooth. Even if great care is exercised initially to properly position each bracket to the marginal ridge, anatomical variations make ideal occlusion difficult to obtain.

Thus the ideal finishing appliance would be an appliance designed to overcome the above difficulties that plague the orthodontist during the finishing stages of treatment and hopefully decreasing treatment time and increasing treatment results.

The Crozat appliance was designed in an attempt to customize a force to each tooth (Lamons 1964). This appliance consists of a basic buccal unit to which may be added auxiliary attachments or springs. The rigid component is for stability and the attachments or springs are for movement of teeth. This appliance does transmit a force to individual teeth with minimal equal and opposite effects, however it has some disadvantages. It is removable and patient cooperation becomes extremely important. There are no brackets on the tooth to control specific types of tooth movements and therefore it does not function well in extraction cases. Because of point contact force applications, it is difficult to obtain extrusion, intrusion, rotation or translation.

The Burstone technique (1966) utilizes a segmented mechanism to the anterior and posterior segments to reduce the reactive forces between the cuspids and bicuspids. Burstone attempted to customize force magnitude, direction and duration. However, during the final stage of finishing, segmental arches were replaced by a continuous arch wire and therefore the same finishing problems existed as mentioned earlier.

One-piece flexible rubber or plastic appliances commonly known as positioners are used by many orthodontists for final finishing following band removal. Kessling (1945) described their fabrication and use. Arch wire adjustment and bracket placement problems are eliminated by using the tooth positioner, however, it has several disadvantages. Force application and magnitude are greatest at the occlusal surface and decrease markedly at the gingival end. Force magnitudes cannot be individualized but are proportional to crown height. Therefore, incisors proportionately can receive more force than molars. Patient cooperation is essential for desirable results because this appliance is removable and requires active biting force to achieve its results.

Another variation of the full-coverage type of positioner made from plastic or rubber known as mini-positioners are also used during the final stages of treatment after band removal. This appliance is designed to enhance the level and alignment of the maxillary and mandibular anterior teeth and aids in closure of band spaces. The fabrication of this appliance can be very similar to the full-coverage type of positioner. There are many variations in design of the mini-positioners.

The purpose of this paper is to introduce a new theoretical finishing appliance which should minimize or eliminate some of the problems encountered in finishing an orthodontic case utilizing current methodology.

METHODS AND MATERIALS

A Buccal Arch Positioner (BAP) consists of two major parts: 1) The rigid component can disperse the force energy transmitted from the flexible components. 2) The flexible components which attach to the brackets at one end and are fastened to the rigid component at the other end.

A model was constructed on a typodont (Columbia Dentoform with Unitek's metal typodont teeth) using preformed bands with .018 x .025 brackets. The case was mounted on a Unitek Orthostudy Articulator (Model 610-100) and the dentition was relocated into an ideal occlusion.

The rigid component was of .068 stainless steel wire which had been heat-treated at 800^{o} F. for ten minutes after first having been contoured to lie 1.5 mm. away from the simulated unattached gingival mucosa and midline frenum. It was also placed into the simulated vestibule without impingment. It was held in place by sticky wax and later keyed with quick-setting plaster so as to expose one-half of the occlusal portion of the rigid component. This procedure was repeated for the opposite arch. After the plaster had set, the keyes were trimmed so that each rigid component could be easily removed or replaced for reference while the flexible components were being constructed. The flexible components for the maxillary and mandibular anterior incisors were constructed of .008 x .020 Hi-T wire (Unitek 245-820), all cuspids and bicuspids were of .010 x .028 Hi-T (Unitek

245-028) and all molar flexible components were constructed of .018 x .025 standard stainless steel wires. The incisors, cuspids and bicuspids had an additional flat wire (.008 or .010) placed to increase the wire size to the bracket size.

Each flexible component was then tied into its respective bracket or tube with .010 stainless steel ligature to maintain stability while the opposite end, adjacent to the rigid component, was adjusted to lie passively as close as possible to the rigid component. The parts were then soldered, using the electric soldering machine, being careful not to anneal the flexible component. The maxillary and mandibular appliances were then ready for removal and polishing. Figure 1A and 1B show the ideal model with the completed BAP appliances placed passively in position. The buccal surfaces of the right and left upper first molar tubes and the right and left lower molar tubes were removed so that measurements were possible in three different spacial positions. Most of the force and displacement of the flexible components were measured using the Correx gauge (Haag-Streit A. G.) and a millimeter ruler. A torquing wrench was made by placing one-half of a bracket slot soldered to the tip of a .068 wire that was graduated every one centimeter from the center of the bracket slot.

After the appliance was placed passively into each bracket, the forces required to displace each flexible component 1 mm. in three different planes (mesio-distal, buccal-lingual and intrusive-extrusive) were measured five times each with the Correx gauge and recorded.

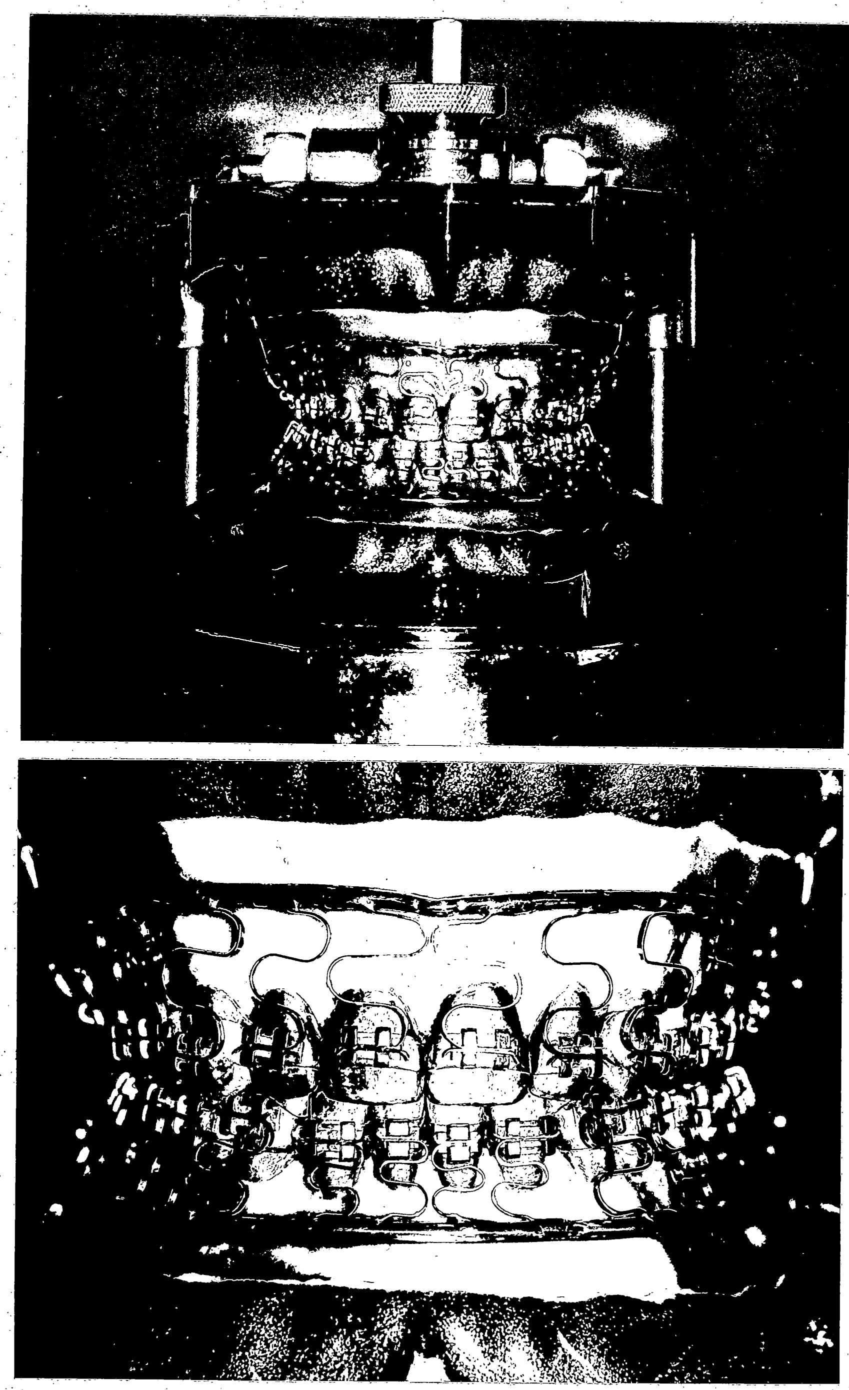

Fig. 1A

Frontal views of the ideal model with the completed BAP appliance placed passively into position.

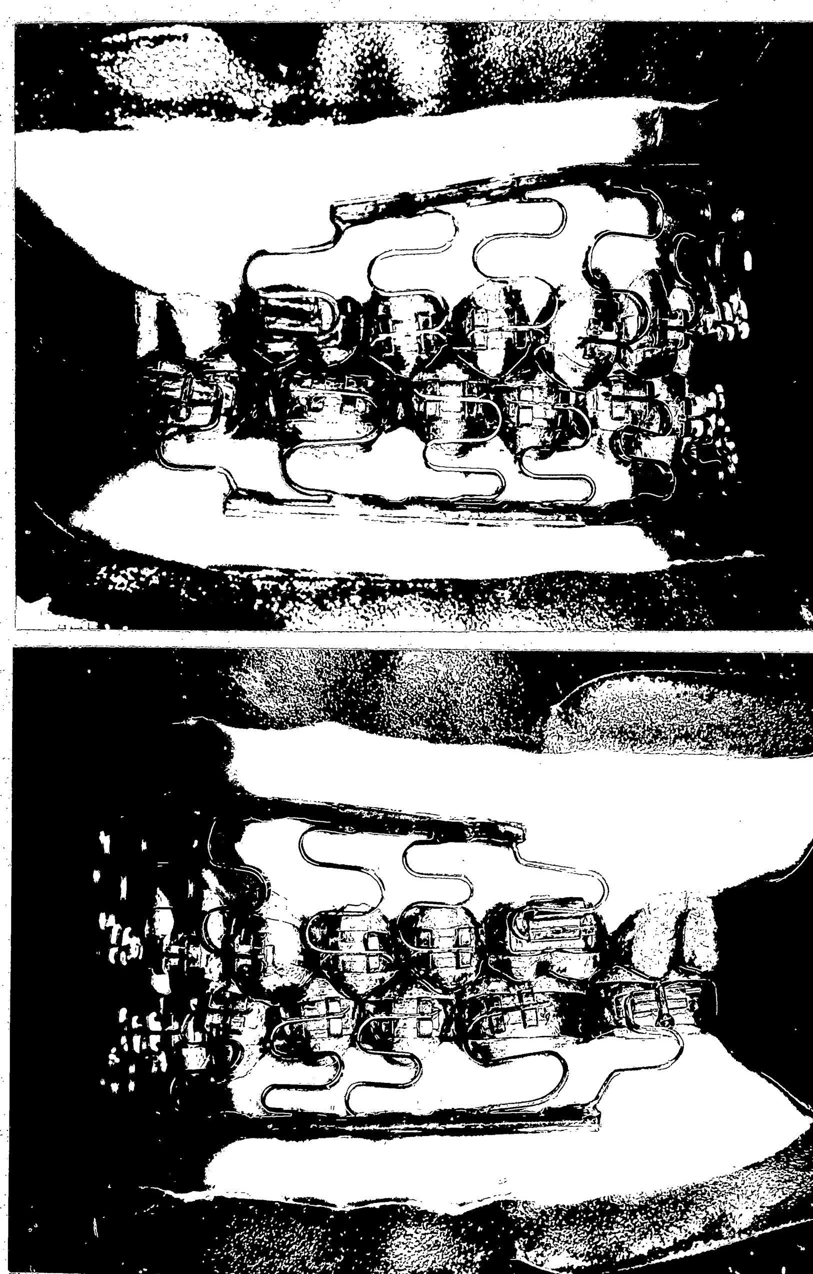

Fig. 1B

Right and left lateral views of the ideal model with the completed BAP appliance placed passively into position prior to removing the buccal surfaces of the molar tubes.

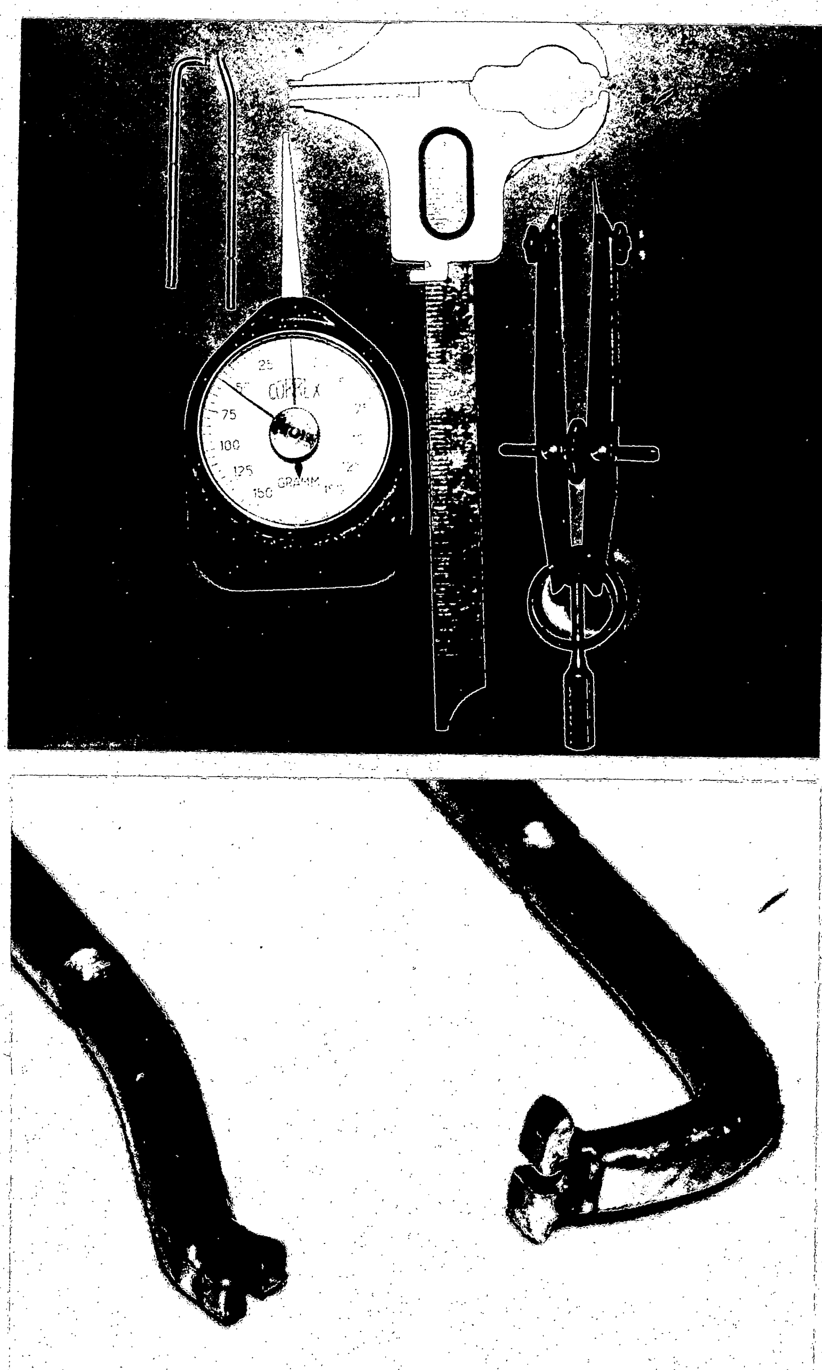

Fig. 2

Illustrations of the measurement devices.

Whenever a torquing force was introduced into the experiment, the torquing wrench was placed on the bracket end of the flexible component and the force was measured by placing the tip of the measuring arm of the Correx gauge on the graduated mark and applying a force until the flexible component would lie passively into the bracket. The force and arm length were recorded. The mean force values and standard error of the means were also calculated.

The movement of the rigid component was also recorded. The distance between the mesio-buccal cusp tip of the first molar most perpendicular to the rigid component was recorded prior to any activation and it was compared again after activation. The same parameters were used in measuring the distance between the cuspid and the rigid component. Mesial displacement of the rigid component was measured with the Dietzgen 4½" Bow Divider by the increased distance, at the junctions of the flexible components, to the right and left last molar tubes. The distance recorded by the divider was quantitated by a Dixon Model 71 Caliper and rounded off to the nearest ¼ mm.

Figure 2 shows an example of each measuring device.

RESULTS

Tables I and II show the mean force necessary to move each flexible component of the maxillary and mandibular appliance a distance of 1 mm. individually in the 3 spacial dimensions while all other flexible components are in a passive bracket position.

Table III shows the mean lingual and distal reciprocal forces and displacements of each flexible component of the mandibular appliance measured individually after the flexible component of the right cuspid was activated lingually 3 mm. with 100 gms. of force. There was approximately 1 mm. mesial movement of all flexible components in the right posterior segment while only 0.5 mm. mesial movement was noted in the left side. These movements resulted in a skewed positioning of the anterior flexible components. Forces in the distal direction of 53 and 23 gms. to the right and left second molar flexible components respectively were required to replace each flexible component to its original position.

Table IV shows the mean buccal and lingual reciprocal forces and displacements of each mandibular flexible component measured individually after the flexible components of the right first and second bicuspids were activated lingually 2 mm. and 1.5 mm. respectively with 50 gms. force to each tooth. The right first and second molars had a net of 15 and 20 gms. respectively of buccal reciprocal force while there were 10 and 13 gms. respectively lingual reciprocal force on the left side. There was no measurable movement of any of the other flexible components.

Table V shows the mean buccal and lingual reciprocal forces and displacements of each mandibular flexible component measured individually after the flexible components of the right and left first and second bicuspids were activated lingually 2 mm. and 1.5 mm. respectively with 50 gms. force each. Only the right first and second molars showed a net reciprocal force of 3 gms. buccally. There was no measurable movement of any other flexible component.

Table VI shows the mean extruding-intruding reciprocal forces and displacements of the right and left cuspid and bicuspid flexible components measured individually after the flexible components of the central incisors were activated 2 mm. with 35 gms. force each and the lateral incisors 1 mm. with 20 gms. force each by intruding or extruding movement. Both flexible components to the cuspids received 10 gms. of reciprocal force and were displaced 0.5 mm. in the reciprocal direction. Both flexible components to the first bicuspids received exactly one-half of all reciprocal forces and displacements compared to that of the cuspids. There were no other measurable reciprocal forces or displacements.

Table VII shows the mean lingual and distal reciprocal forces and displacements of each flexible component of the mandibular appliance measured individually after the flexible components of the right and left cuspids were activated lingually 3.0 mm. and 3.5 mm. respectively with 100 gms. force each. There was approximately 1 mm. bilateral mesial movement of all the flexible components in the posterior segments. This movement resulted in a symmetrical positioning of the anterior flexible components approximately 1 mm. buccally to the brackets. Forces of 63 and 61 gms. respectively to the right and left second molar flexible components in a distal direction were required to replace each flexible component to the passive bracket position.

Table VIII shows the mean extruding and distal reciprocal forces and displacements of each maxillary flexible component measured individually after the flexible components of the central incisors were activated 45° to the brackets with 50 gms.-cm. each and the lateral incisors 35° with 35 gms.-cm. each with lingual root torquing force. All remaining flexible components moved mesially approximately 1 mm. This movement resulted in extruding both flexible components to the cuspids .25 mm. with 5 gms. of reciprocal extrusion force. Forces of 62 and 60 gms. respectively were applied in a distal direction to the right and left first molar flexible components to replace each flexible component into a passive bracket position. There was no measurable reciprocal movement of any of the other flexible component.

Table IX shows the mean extrusion and distal reciprocal forces and displacement of each flexible component of the maxillary appliance. They were measured individually after the flexible components of the right and left cuspids were activated lingually 4.5 mm. and 4.0 mm. respectively with 100 gms. force each. Lingual root torquing forces to the central incisors with 50 gms.-cm. force each and the lateral incisors with 35 gms.-cm. force each were also included. There were bilateral mesial movements of approximately 2.3 mm. to all posterior flexible components. Forces of 143 and 146 gms. respectively to the first and second molar flexible components in a distal direction were required to replace each flexible component into a passive bracket position. There was no measurable reciprocal movement of any of the other flexible components.

Table X shows the lingual and distal reciprocal force and displacement of each flexible component of the mandibular appliance measured individually after the flexible components of the right and left cuspids were activated lingually 3.0 mm. and 3.5 mm. respectively with 100 gms. force each while the right and left flexible components of the first and second molars were immobilized. There was no measurable reciprocal force or displacement to any of the flexible components.

Table XI shows the extruding and distal reciprocal force and displacement of each maxillary flexible component measured individually after the flexible components of the central incisors were activated 45^{o} to the brackets with 50 gms.-cm. force to each and the lateral incisors 35^{o} with 35 gms.-cm. force each with lingual root torquing forces while the flexible components to the right and left first molars were immobilized. There were no measurable reciprocal forces or displacements measured to any flexible components.

Table XII shows the extrusion and distal reciprocal force as well as displacement of each maxillary flexible component measured individually after the flexible components to the right and left cuspids were activated lingually 4.5 and 4.0 mm. respectively with 100 gms. force to each and lingual root torquing forces to the central incisors with 50 gms.-cm. force to each and the lateral incisors with

35 gms.-cm. force each while both molar flexible components were immobilized. There were no measurable reciprocal forces or displacements of any of the flexible or rigid components.

TABLE I

Forces* required to displace the maxillary individual flexible components 1 mm. when all other flexible components were in the passive bracket position.

TOOTH		DIRECTION		
R	L	Buccal-Lingual	Mesio-Distal	Intrusion-Extrusion
1		16 ± 0.63**	5 ± 0	21.2 ± 0.48
	1	17 ± 0.54	5 ± 0	23.8 ± 0.73
2		16 ± 0.44	5 ± 0	25.8 ± 0.48
	2	17 ± 0.83	5 ± 0	21.8 ± 0.91
3		37 ± 1.22	12.6 ± 0.60	47 ± 1.22
	3	41 ± 1.0	13.8 ± 0.73	58 ± 1.22
4		29 ± 1.0	13.8 ± 0.73	52 ± 1.22
	4	32 ± 1.22	13.2 ± 0.73	44 ± 1.00
5		33 ± 1.22	14.4 ± 0.60	47 ± 1.22
	5	42 ± 1.22	14.4 ± 0.60	48 ± 1.22
6		61 ± 1.0	74 ± 1.00	137 ± 1.22
	6	63 ± 1.22	82 ± 1.22	131 ± 1.00

* The mean in grams.

** Standard error of the mean.

TABLE II

Forces* required to displace the mandibular individual flexible components 1 mm. when all the other flexible components were in the passive bracket position.

TOOTH R	TOOTH L	DIRECTION Buccal-Lingual	Mesio-Distal	Intrusion-Extrusion
1		26 ± 1.0**	12.6 ± 0.60	41 ± 1.00
	1	27 ± 1.22	14.8 ± 0.80	43 ± 1.22
2		25 ± 0	14.4 ± 0.60	43 ± 1.22
	2	21 ± 1.0	14.4 ± 0.60	41 ± 1.00
3		35.6 ± 0.6	15.8 ± 0.48	67 ± 1.22
	3	38. ± 1.22	13.8 ± 0.73	53 ± 1.22
4		28 ± 1.22	14.4 ± 0.60	54 ± 1.00
	4	29 ± 1.0	13.2 ± 0.73	58 ± 1.22
5		36 ± 1.0	15.6 ± 0.60	51 ± 1.00
	5	34 ± 1.0	15.4 ± 0.40	59 ± 1.00
6		58 ± 1.22	90 ± 1.58	112 ± 1.22
	6	56 ± 1.0	85 ± 1.58	118 ± 1.22
7		82 ± 1.22	91 ± 1.00	139 ± 1.00
	7	73 ± 1.22	93 ± 1.22	151 ± 1.00

* The means in grams.

** Standard error of the mean.

TABLE III

Mean force and displacement of each mandibular flexible component required to replace each flexible component individually into a passive bracket position following the right cuspid flexible component lingually activated with 100 gms. force.

TOOTH		DIRECTION			
		Lingual		Distal	
R	L	Reciprocal Force (gms.)	Reciprocal Displacement (mm.)	Reciprocal Force (gms.)	Reciprocal Displacement (mm.)
1		5 ± 0*	0.75 ± 0.10*	3 ± 0*	0.25 ± 0 *
	1	5 ± 0*	0.50 ± 0.08*	0	0
2		5 ± 0*	0.75 ± 0.09*	5 ± 0*	0.5 ± 0.07*
	2	3 ± 0*	0.25 ± 0 *	0	0
3		**	**	**	**
	3	0	0	*	0.5 ± 0.09*
4		0	0	*	1.1 ± 0.13*
	4	0	0	*	0.5 ± 0.05*
5		0	0	*	0.9 ± 0.08*
	5	0	0	*	0.5 ± 0.08*
6		0	0	*	0.9 ± 0.14*
	6	0	0	*	0.5 ± 0.06*
7		0	0	53 ± 1.22	1.0 ± 0.22*
	7	0	0	23 ± 1.22	0.5 ± 0.07*

* After forces were applied in a distal direction to the most rigid flexible components (right & left second molars), all reciprocal forces and displacements returned to a zero measurement.

** Tooth being activated.

TABLE IV

Mean force and displacement of each of the mandibular flexible components required to replace each flexible component individually into a passive bracket position following activation of the right first and second bicuspid in a lingual direction of the flexible components with 50 gms. force each followed by skewing of the rigid component to the right.

TOOTH		DIRECTION			
		Buccal		Lingual	
R	L	Reciprocal Force (gms.)	Reciprocal Displacement (mm.)	Reciprocal Force (gms.)	Reciprocal Displacement (mm.)
1		0	0	0	0
	1	0	0	0	0
2		0	0	0	0
	2	0	0	0	0
3		0	0	0	0
	3	0	0	0	0
4		*	*	*	*
	4	0	0	0	0
5		*	*	*	*
	5	0	0	0	0
6		15 $\pm$ 1.22	0	0	0
	6	0	0	10 $\pm$ 1.0	0
7		20 $\pm$ 1.22	0	0	0
	7	0	0	13 $\pm$ 1.0	0

* The teeth that were activated.

TABLE V

Mean force and displacement of each mandibular flexible component required to replace each flexible component individually into a passive bracket position following the bilateral first and second bicuspid activations in a lingual direction with 50 gms. force to each tooth.

TOOTH R	TOOTH L	DIRECTION Buccal Reciprocal Force (gms.)	Buccal Reciprocal Displacement (mm.)	Lingual Reciprocal Force (gms.)	Lingual Reciprocal Displacement (mm.)
1		0	0	0	0
	1	0	0	0	0
2		0	0	0	0
	2	0	0	0	0
3		0	0	0	0
	3	0	0	0	0
4		*	*	*	*
	4	*	*	*	*
5		*	*	*	*
	5	*	*	*	*
6		3 ± 1.0	0	0	0
	6	0	0	0	0
7		3 ± 1.0	0	0	0
	7	0	0	0	0

* The teeth that were activated.

TABLE VI

Mean force and displacement of each of the maxillary flexible component required to replace each flexible component individually into a passive bracket position following intrusion or extrusion of the four incisor flexible components with a total force of 110 gms.**

TOOTH		DIRECTION			
		Extrusion		Intrusion	
R	L	Reciprocal Force (gms.)	Reciprocal Displacement (mm.)	Reciprocal Force (gms.)	Reciprocal Displacement (mm.)
1		*	*	*	*
	1	*	*	*	*
2		*	*	*	*
	2	*	*	*	*
3		10 ± 0	0.5 ± .05	10 ± 0	0.5 ± .09
	3	10 ± 0	0.5 ± .07	10 ± 0	0.5 ± .08
4		5 ± 0	0.25 ± 0.0	5 ± 0	0.25 ± 0.0
	4	5 ± 0	0.25 ± 0.0	5 ± 0	0.25 ± 0.0
5		0	0	0	0
	5	0	0	0	0
6		0	0	0	0
	6	0	0	0	0

* The teeth that were activated.

** Separate experiments were performed for the intruding and extruding forces but they were recorded in this single Table.

TABLE VII

Mean force and displacement of each of its mandibular flexible component required to replace each flexible component individually into a passive bracket position following lingual activation of the cuspids with a force of 100 gms. each.

TOOTH R	TOOTH L	Lingual Reciprocal Force (gms.)	Lingual Reciprocal Displacement (mm.)	Distal Reciprocal Force (gms.)	Distal Reciprocal Displacement (mm.)
1		25 ± .73*	0.9 ± 0.09*	0	0
	1	25 ± 1.22*	1.1 ± 0.14*	0	0
2		25 ± 1.22*	0.9 ± 0.17*	0	0
	2	20 ± 1.22*	1.0 ± 0.12*	0	0
3		**	**	**	**
	3	**	**	**	**
4		0	0	0	1.0 ± 0.18*
	4	0	0	*	0.9 ± 0.16*
5		0	0	*	1.0 ± 0.17*
	5	0	0	*	1.1 ± 0.08*
6		0	0	*	0.9 ± 0.12*
	6	0	0	*	0.9 ± 0.13*
7		0	0	63 ± 1.22	0.9 ± 0.15*
	7	0	0	61 ± 1.0	1.0 ± 0.18*

* After the force was applied in a distal direction to the most rigid flexible components (right and left second molars), all the reciprocal forces and displacements returned to zero.

** The teeth that were activated.

TABLE VIII

Mean force and displacement of each maxillary flexible component required to replace each flexible component individually into the passive bracket position following lingual root torquing of the four incisor flexible component with a total force of 170 gms.-cm.

TOOTH		DIRECTION			
		Extrusion		Distal	
R	L	Reciprocal Force (gms.)	Reciprocal Displacement (mm.)	Reciprocal Force (gms.)	Reciprocal Displacement (mm.)
1		*	*	*	*
	1	*	*	*	*
2		*	*	*	*
	2	*	*	*	*
3		5 ± 0**	.25 ± 0**	**	1.0 ± 0.18**
	3	5 ± 0**	.25 ± 0**	**	1.0 ± 0.13**
4		0	0	**	0.9 ± 0.12**
	4	0	0	**	1.1 ± 0.08**
5		0	0	**	1.1 ± 0.20**
	5	0	0	**	1.1 ± 0.19**
6		0	0	62 ± 1.22	0.9 ± 0.21**
	6	0	0	60 ± 0.0	0.9 ± 0.24**

* The teeth that were activated.

** After force was applied in a distal direction to the most rigid flexible component (right and left first molars), all reciprocal forces and displacements returned to zero.

TABLE IX

Mean force and displacement of each maxillary flexible component required to replace each flexible component individually into a passive bracket position following bilateral cuspid lingual activation with 100 gms. force each and four incisors with a total lingual root torque force of 170 gms.-cm.

TOOTH		DIRECTION			
		Extrusion		Distal	
R	L	Reciprocal Force (gms.)	Reciprocal Displacement (mm.)	Reciprocal Force (gms.)	Reciprocal Displacement (mm.)
1		*	*	*	*
	1	*	*	*	*
2		*	*	*	*
	2	*	*	*	*
3		*	*	*	*
	3	*	*	*	*
4		5 ± 0**	.25 ± 0**	**	2.4 ± 0.33**
	4	5 ± 0**	.25 ± 0**	**	2.3 ± 0.40**
5		0	0	**	2.4 ± 0.29**
	5	0	0	**	2.3 ± 0.41**
6		0	0	143 ± 1.22	2.3 ± 0.48**
	6	0	0	146 ± 1.22	2.2 ± 0.53**

* The teeth that were activated.

** After the forces were applied in a distal direction to the right and left first molar flexible components, all reciprocal forces returned to zero.

TABLE X

Reciprocal force and displacement of each mandibular flexible component by immobilization of all molar flexible components following bilateral lingual activation of the cuspid flexible components with 100 gms. force to each component.

TOOTH		DIRECTION			
		Lingual		Distal	
R	L	Reciprocal Force (gms.)	Reciprocal Displacement (mm.)	Reciprocal Force (gms.)	Reciprocal Displacement (mm.)
1		0	0	0	0
	1	0	0	0	0
2		0	0	0	0
	2	0	0	0	0
3		*	*	*	*
	3	*	*	*	*
4		0	0	0	0
	4	0	0	0	0
5		0	0	0	0
	5	0	0	0	0
6		**	**	**	**
	6	**	**	**	**
7		**	**	**	**
	7	**	**	**	**

* The teeth that were activated.

** The immobilized teeth.

TABLE XI

Reciprocal force and displacement of each maxillary flexible component by immobilization of both molar flexible components following four incisor flexible components that were activated with a total force of 170 gms.-cm. of lingual root torque.

TOOTH		DIRECTION			
		Extrusion		Distal	
R	L	Reciprocal Force (gms.)	Reciprocal Displacement (mm.)	Reciprocal Force (gms.)	Reciprocal Displacement (mm.)
1		*	*	*	*
	1	*	*	*	*
2		*	*	*	*
	2	*	*	*	*
3		0	0	0	0
	3	0	0	0	0
4		0	0	0	0
	4	0	0	0	0
5		0	0	0	0
	5	0	0	0	0
6		**	**	**	**
	6	**	**	**	**

* The teeth that were activated.

** The immobilized teeth.

TABLE XII

Reciprocal force and displacement of each maxillary flexible component by immobilization of both molar flexible components following the activation of the flexible components of both cuspids lingually with 100 gms. force to each tooth and the four incisors with a total force of 170 gms.-cm. lingual root torque.

TOOTH		DIRECTION			
		Extrusion		Distal	
R	L	Reciprocal Force (gms.)	Reciprocal Displacement (mm.)	Reciprocal Force (gms.)	Reciprocal Displacement (mm.)
1		*	*	*	*
	1	*	*	*	*
2		*	*	*	*
	2	*	*	*	*
3		*	*	*	*
	3	*	*	*	*
4		0	0	0	0
	4	0	0	0	0
5		0	0	0	0
	5	0	0	0	0
6		**	**	**	**
	6	**	**	**	**

* The teeth that were activated.

** The immobilized teeth.

DISCUSSION

The stage at which "finishing" a case has its beginning varies with the orthodontist. In this study, however, certain assumptions were made regarding the position of the teeth at the beginning of the finishing stage. 1) The mandibular teeth required adjustments in the horizontal plane only. 2) The posterior segments were in reasonable cuspal interdigitation, however not necessarily in a proper finished position. 3) The maxillary anterior segment required lingual root torque and intrusion.

Since the principles of the appliance design and the mechanics would be similar in either arch, the intrusion and torque of the lower anterior flexible components were not measured.

The rigid component disperses the force energy transmitted from all the flexible components along the full length of the wire. The placement of this rigid component into the vestibule is determined by the position of the midline frenum, the muscular activities at their maximum contracted positions and muscular habits. The distance between the soft tissue of the alveolar process and the rigid component is critical and will be discussed later.

The flexible component could be attached to teeth in numerous ways including any one of the currently standard band-bracket assemblies. They may be fastened to the rigid component permanently by soldering or plastic bonding or may be removable so that other flexible components could be easily inserted.

The flexible component can deliver an optimum physiologic force magnitude at a relatively low rate of force over a relatively long duration which can give both a low stiffness and a high deformability by the proper selection of wire diameter and shape, increased wire length, design and number of helical loops or variations in design, and the structural properties of a selected wire. Obviously, the smaller wire size with greater wire length incorporated into the design of each flexible component will produce a lighter force. Weinstein (1967) stated that if the operator is highly concerned about the biologic entity with which he works, he must then select the appliances that will deliver forces of a relatively low order of magnitude over a long duration.

Schwarz (1932), Reitan (1969), Gianelly and Goldman (1971) and Ricketts (1973) and many others have mentioned and/or quantitated light forces for tooth movement. Schwarz (1932) stated that force magnitudes in excess of 26 gms. per square centimeter was thought to strangulate the periodontal tissue, cause tissue necrosis or even force the tooth into physical contact with the bone. Oppenheim (1944) and Gianelly (1969) showed the importance of maintaining patent vessels during physiologic tooth movement. Most forces used to move teeth vary from 15 to 300 gms. "Lighter" forces are those which are generally less than 50-75 gms. whereas "heavy" forces usually represent more than 150 gms. The appliance was constructed, taking into consideration the above factors, for each arch to see if it would be possible to fabricate flexible components with custom-designed force magnitude, duration and direction to each tooth and thereby greatly reduce the problems related to undesirable reciprocal forces, bracket height placements and individual adjustments.

Tables I and II tabulated the mean forces to each flexible component in 3 spacial directions for the maxillary and mandibular appliances. Readings of less than 15 gms. were interpolations on the ungraduated scale portion of the Correx gauge and were not considered accurate. All five mesio-distal displacement readings for each maxillary incisor flexible components were 5 gms. each resulting in zero standard error of the mean. Force magnitudes in the horizontal plane to most flexible components are within an acceptable range. Those that are not can easily be adjusted to increase or decrease the force magnitudes by altering the amount of displacement of the flexible components. The mesio-distal and intrusion-extrusion forces were measured by placing a small metal hook and laterally displacing each flexible component until it was just free to be moved in the given directions. Forces lingually were not measured because of displacement problems. However, since mesial forces were equal to distal forces and intrusion forces equal to extrusion forces over a given 1 mm. distance, it may be reasonable to assume that the buccal displacement force of 1 mm. would equal the lingual displacement force of 1 mm. Intrusion forces which were of great concern were only of those flexible components to the maxillary anterior incisors. These were all within the optimum force magnitude range.

If a force with a mesial vector was applied unilaterally (Table III), there was skewing and labial displacement of the midline to the opposite side and there could be more anchorage loss on the side of the applied force than the opposite side. However, this mesial reciprocal force on the side of force application was quite small 53 ± 1.22 gms. If this force could be distributed to the entire right posterior segment by tying each flexible component back, anchorage problem would be greatly reduced. The opposite side showed a total 23 ± 1.22 gms. which could also be distributed to its entire posterior segment. These procedures could result in effective movement of the tooth or teeth to which the force was applied and could prevent skewing and displacement of the midline.

If forces with a lateral vector were applied unilaterally to the posterior segment (Table IV), there was no visual displacement of any flexible component. However, in the passive state the mean buccal displacement forces of the right first and second molars were 58 gms. and 82 gms. respectively (see Table II). Upon activation of both bicuspids, the same first and second molars reduced their buccal mean forces to 43 gms. and 62 gms. respectively. This provided net buccal reciprocal forces of 15 gms. and 20 gms. On the left side the passive mean buccal displacement forces were 56 gms. and 73 gms. to the first and second molars respectively. Upon activation of the mentioned bicuspids, these mean molar buccal displacement forces increased to 66 and 86 gms. This produced net lingual reciprocal forces of 10 gms. and 13 gms. respectively.

Table V shows that the same lateral displacement forces were applied bilaterally. All reciprocal forces nearly cancelled each other. Reciprocal forces buccally show 3 gms. each to the right first and second molars. These figures were calculated by taking the original passive mean forces of 58 gms. and 82 gms. for the right first and second molars. After bilateral activation, the force required to displace the flexible components to the same teeth read 55 and 79 gms. each netting 3 gms of reciprocal force. The difference of measurements on the left side was exactly zero. Measurement error may account for this reciprocal force. Clinically, bilateral reciprocal forces probably exist more often than not since most teeth will require some type of movement.

Extruding and intruding reciprocal forces were recorded in Table VI. Immediate adjacent flexible components to the area of activation (110 gms. to anteriors) showed only 10 gms. and the bicuspid area showed 5 gms. These amounts were considerably less than with the conventional arch wire.

If forces with mesial vectors were applied bilaterally (Tables VII and VIII), there was no skewing of the midline but only labial displacement. This could result in bilateral anchorage loss. However, the reciprocal forces were 63 $\pm$ 1.22 gms. to the lower right second molar and 61 $\pm$ 1.0 gms. to the left second molar. If these forces could be distributed to each posterior segment as previously mentioned, anchorage problems are again greatly reduced and mesial displacement of anterior segment could be reduced.

Experiments VII and VIII were combined to obtain maximum reciprocal mesial vectors during finishing of the maxillary anterior segment (Table IX). There were approximately 2.3 mm. bilateral mesial movements of all posterior flexible components. The rigid component at the midline moved 2.3 mm. anteriorly but maintained symmetry. Slight extrusive displacement was noticed on the first bicuspids. Reciprocal intrusion force to the molar regions was not measurable. Mesial forces to the posterior segments were of such magnitude (143 and 146 gms. to the right and left first molars) that one should consider directional extraoral forces in order to preserve molar anchorage. The resultant forces at the molars were just slightly larger than the sums of the resultants in the two previous experimental configurations.

Tables X, XI and XII show that by immobilizing the flexible components to the molars bilaterally, all remaining flexible components showed no measurable reciprocal force. One can conclude that all reciprocal forces from the flexible components of the activated teeth dissipated to all remaining flexible components via the rigid component. If the summation of forces was less than or within the minimum energy required to displace the selected wire size, design and properties of each flexible component, the reciprocal forces were impossible to measure with the Correx gauge.

It was previously mentioned that mesial vectors can cause anchorage problems but may be greatly reduced by distributing the force to the entire posterior segments.

If molars are in good cuspal interdigitation, it would be very advantageous to use more rigid flexible components to the posterior segments. Carrying this idea further, Class I malocclusion cases with reasonably good posterior occlusion could be placed immediately into the BAP appliance for finishing because mesial vector problems could be resolved by utilizing proper anchorage resistance and buccal-lingual reciprocal forces may cancel each other or reduce them to a magnitude that they are no longer a problem. The more stationary the posterior segments become, the more efficient the BAP appliance will function to move anterior teeth during finishing.

The cuspal interdigitation of the posterior segments becomes a major criteria for anchorage preservation. One must analyze differential forces before immobilizing the posterior segments for maximum efficiency of anterior teeth adjustments during the finishing stages. Additional factors that aid anchorage preservation are muscle exercises, strategic placement of the rigid component and tooth positioning. Posterior temporalis muscle exercises tend to drive the mandibular segments posteriorly by the distal vector of force during this muscle contraction. This factor in relation to good cuspal interdigitation will tend to drive the maxillary posterior dentition distally thereby preserving considerable anchorage. Abnormal tongue thrusting and mandible positioning habits become major factors against anchorage. These muscle problems should be well in control by the time finishing stage begin. The other environmental factor influencing anchorage would be the placement of the rigid component into the vestibule. This rigid component not only acts as a lip bumper which aids in anchorage preservation but it can act as an appliance to remind the patient of his muscle habit or habits and can exercise or relax the unbalanced muscles which will ultimately be an invaluable asset during the retention stages. The BAP can also aid in relieving the habitual muscle forces of constricting the dental arches (buccinators, orbicularis oris and mentalis muscles) and allow the tongue to aid in the expansion of the dental arches laterally as well as allowing the incisors to move labially in the anterior segment. This will also permit the flexible components to express themselves to the passive ideal setup occlusion as originally fabricated at a controlled optimum magnitude of force. In cases where a patient has loose, flabby lips, one may position the rigid component more labially if anchorage maintenance is to play its role in resolving this particular case during the finishing stages.

Another important factor in anchorage preservation is the positioning of teeth. One can take advantage of anatomic variations mentioned by Reitan (1964) and Ricketts (1973) in several areas. The mandibular first molar roots can be tucked well into the buccal cortical plate just behind and beneath the oblique ridges. This aids anchorage preservation while retracting cuspids or anterior segments. The cuspid roots can be torqued lingually so no excessive prominent cortical plate is palpable labially to their roots during cuspid retraction. Torquing teeth in an arc simultaneously with intrusion and distal movements will aid greatly in anchorage preservation along with directional extraoral forces to the rigid component.

To the contrary, if molar anchorage is not necessary and if there need be mesial movement of the molars or the posterior segments one can reconsider anatomical variation and redesign their flexible components with less resistance and use different wire properties so that the rigid component will move mesially when finishing the anterior segment. This allows the posterior segments to slip anteriorly to close the extraction space and maintain good profile.

Segmental BAP appliances can also be constructed by using .045 stainless steel wire for the rigid component. This is contoured and made to fit into the conventional headgear tubes of the molar bands and is then heat-treated. Flexible components, for example the right and left cuspids, can be designed, fabricated and soldered to the rigid component. The appliance can be tied into the molar tubes and immobilized. The flexible components to both cuspids can be activated into the desired positions, measured and tied into their respective brackets. This would produce an efficient BAP appliance since the conventional arch wire, by-passing the cuspids but engaging all other brackets and molar tubes, will give rigidity to the molar anchorage in this given situation. The lateral displacements from either side will usually negate the undesirable reciprocal forces. Another example would be to bring an impacted cuspid down into occlusion via series of mechanics utilizing the flexible component designed for light force magnitude in a given direction over a long duration.

Oral hygiene would not be anticipated to be a major problem. Normal hygiene procedures should adequately clean the appliance and dentition. Valid evaluations will have to wait until the appliances are placed intraorally and clinically observed.

The time involved in the fabrication of the first maxillary complete BAP appliance was approximately six hours. However, much time was spent in designing and redesigning, soldering and resoldering very small flexible components to a much larger rigid component yet not annealing the flexible components. As one became more familiar with design, wire properties and soldering, the mandibular BAP appliance could be fabricated in approximately four hours. The improvement in fabrication time can only be reduced to a certain point. Therefore, the question of whether one spends approximately 3-4 hours designing and fabricating the BAP appliance a single time or spending many extra chair hours fabricating numerous finishing arch wires coping with uneven bracket locations, angulations and undesirable reciprocal forces becomes the major issue. One must weigh the advantages over the disadvantages and make his own decision.

SUMMARY

Maxillary and mandibular BAP appliances were constructed to see if it would be possible to fabricate flexible components with custom-designed force magnitude and direction to each tooth. Reciprocal force reactions were quantitated. Unilateral activation with a mesial vector caused skewing and anterior displacement of the midline with minimal mesial reciprocal forces to the molar anchorage on the side of activation. Bilateral activations in the buccal-lingual directions to the posterior segments cancelled out their reciprocal reactions. Bilateral intrusion or extrusion reciprocal forces were reduced greatly to the immediate adjacent teeth proportionately not attainable by the conventional technique during finishing. Bilateral activations with mesial vectors did not cause midline skewing but contributed considerable more mesial force to the posterior segments, however it was well within the range to maintain anchorage preservation. All skewing or mesial displacements of the flexible components can be avoided by immobilizing the flexible components to the last molars bilaterally and possibly fabricating these components utilizing heavier resistance design and wire properties. These above factors can cause anchorage preservation problems if the summation of mesial vectors are of great magnitudes. In these cases, the placement of the rigid component into the vestibule, the anatomical variation and the directional extraoral force should be reconsidered.

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DEVELOPMENT AND ANALYSES OF A NEW IDEAL FINISHING APPLIANCE

by

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ABSTRACT

The purpose of this paper is to introduce a new theoretical finishing appliance which should reduce the problems encountered during finishing with the present appliances. Maxillary and mandibular Buccal Arch Positioner appliances were constructed on a model that could deliver custom-designed force magnitude and direction to each tooth.

The mean force and displacement of 1 mm. for each flexible component were quantitated individually while all other flexible components were in a passive bracket position to see if the force magnitude to each tooth was constructed properly. Various hypothetical situations were quantitated. Unilateral mesial vectors caused skewing and labial displacement of the midline with minimal mesial forces to the posterior segments. Bilateral buccal-lingual vectors to the posterior segment cancelled out their reciprocal reactions. Bilateral intrusion or extrusion reciprocal forces were reduced greatly to the immediate adjacent teeth. Bilateral mesial vectors did not cause midline skewing but added considerably more mesial force to the posterior segments but well within the range to maintain anchorage. All skewing and displacements of flexible components can be avoided by immobilizing the flexible components to the last molars bilaterally. If the summation of mesial vectors are of great magnitude, anchorage preservation could become a problem. In such cases, placement of the rigid component into the vestibule, anatomical variation and directional extraoral force should be reanalyzed.